

2012 SLaMS Workshop

Wallops Flight Facility 6U Satellite and Deployment System

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NASA Wallops Flight Facility

- What is a CubeSat?
- What is SSAT?
- Phase 1
- Phase 2
 - Satellite
 - Deployer
 - Deployment
 - Analysis
 - Manufacturing & Assembly
 - Testing
- Lessons Learned
- Forward Work



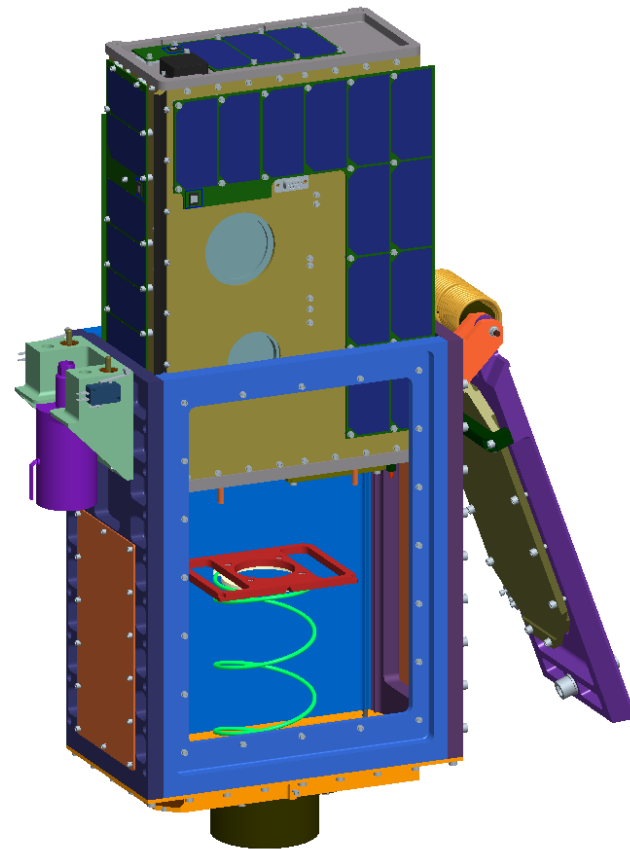
Minotaur I launching from Wallops Flight Facility with CubeSats on board

What is a CubeSat?

- Nanosatellites that adhere to the CubeSat standard
 - Ranges from 1 to 3U in size
 - 1U is 10 x 10 x 10cm and has a mass allocation of 1kg
- Fly as secondary payloads and are ejected from a deployer (P-POD)
- Commonly viewed as:
 - University educational platforms
 - Limited in science capability
 - Lower “quality” spacecraft
- Investment in this technology through private industry and government agencies such as the DOD have yielded significant advancements
- Science community has interest in the potential of a 6U size satellite to achieve higher level of science
 - 6U = 12 kg and volume of $\approx 433 \text{ in}^3$

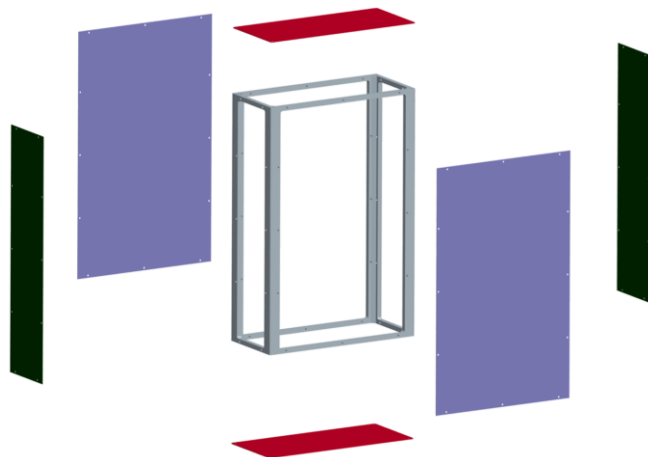


- SSAT or Small Satellite Advanced Technology project occurred from October 2009 – December 2011
- 1 of 5 projects based on part of a \$5 million allocation to Wallops Flight Facility per a targeted NASA appropriation
- Primary objective was to develop a 6U satellite and deployer in response to the growing interest of the science community
- The goal was to advance CubeSat technology to a more professional level and provide capability necessary for a higher degree of science
- The initial plan was to design, build, test, and launch the 6U for an earth science mission
- Unfortunately, the instrument (CloudSat) experienced funding issues, WFF work outpaced the instrument schedule, and the project ran out of time

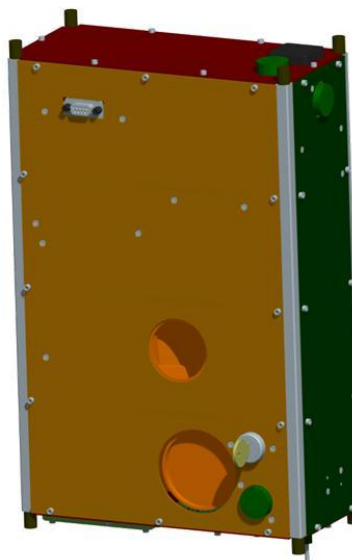


SSAT 6U Satellite & Deployer

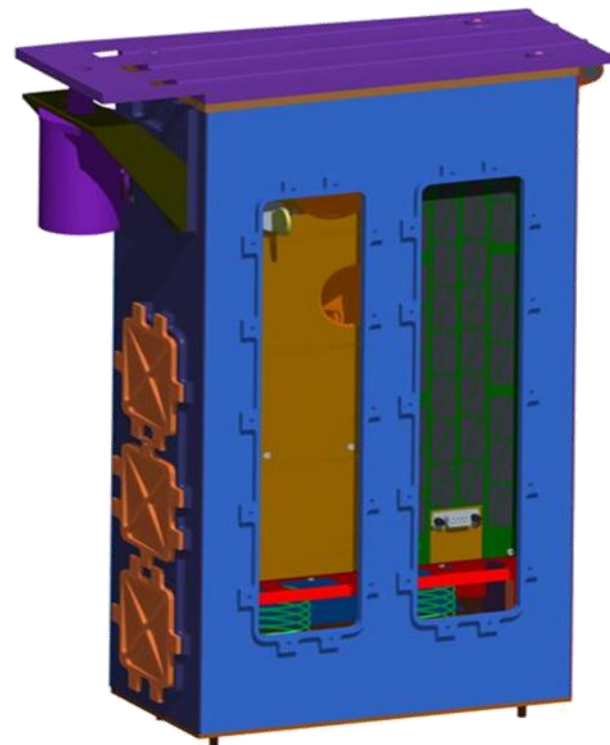
- Directed to design a CubeSat style satellite & multi-payload deployer
 - CubeSat style = 4 corner guide rail system
- Learned about the shortcomings of the CubeSat satellite constraint system and the need to decouple the guide rails from the primary load path



1 piece frame & panel
satellite structure



Preloaded friction constraint
at the (8) corners

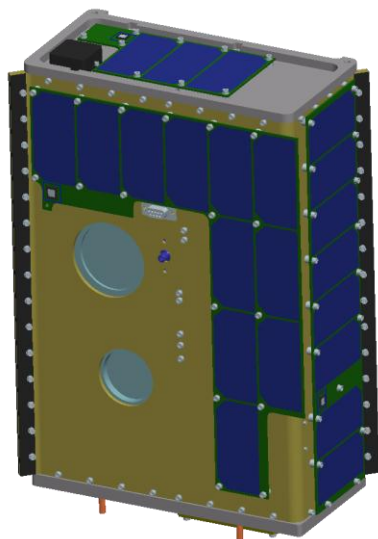


Deployer internal volume
sized to accommodate (2) 3U
satellites

Ran into issues with plastic
deformation at the corner
constraint

Phase 2

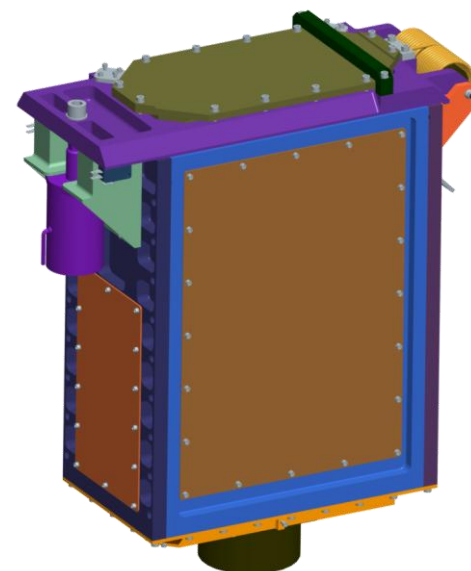
- Trade space opened beyond CubeSat style to address constraint system
- Moved to a two guide rail system and focused on a single payload deployer



Satellite



**Satellite within Deployer
with two guide rails**



Deployer

Phase 2: Satellite Design

External Dimensions:

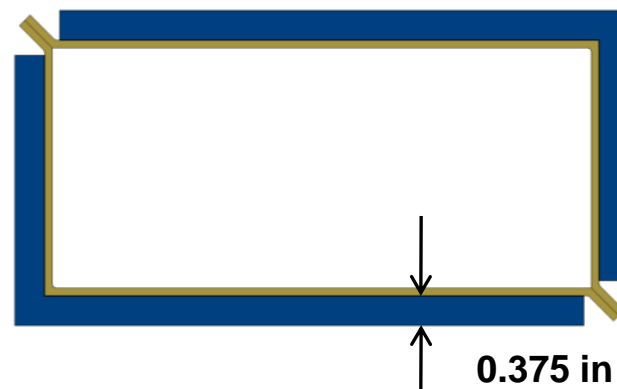
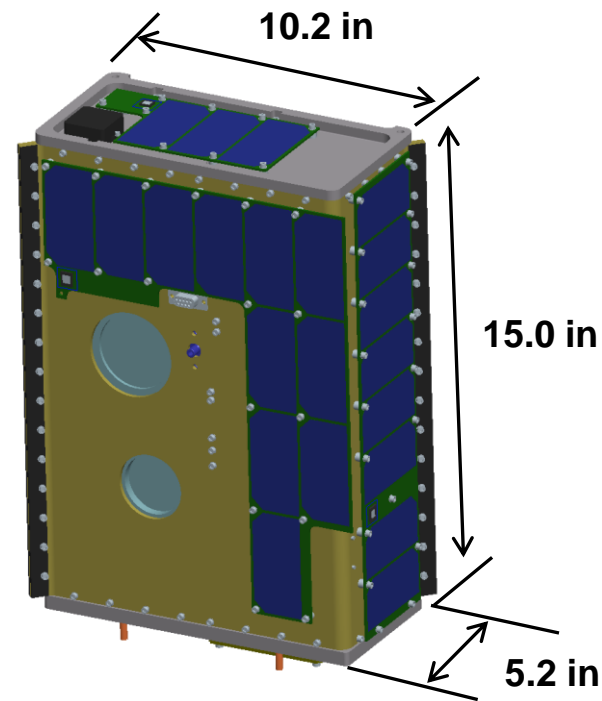
- 15.0 x 10.2 x 5.2 in (38.1 x 26 x 13.3 cm)
- 0.375 in (0.95 cm) protrusion from the panel outer surface

Internal Volume:

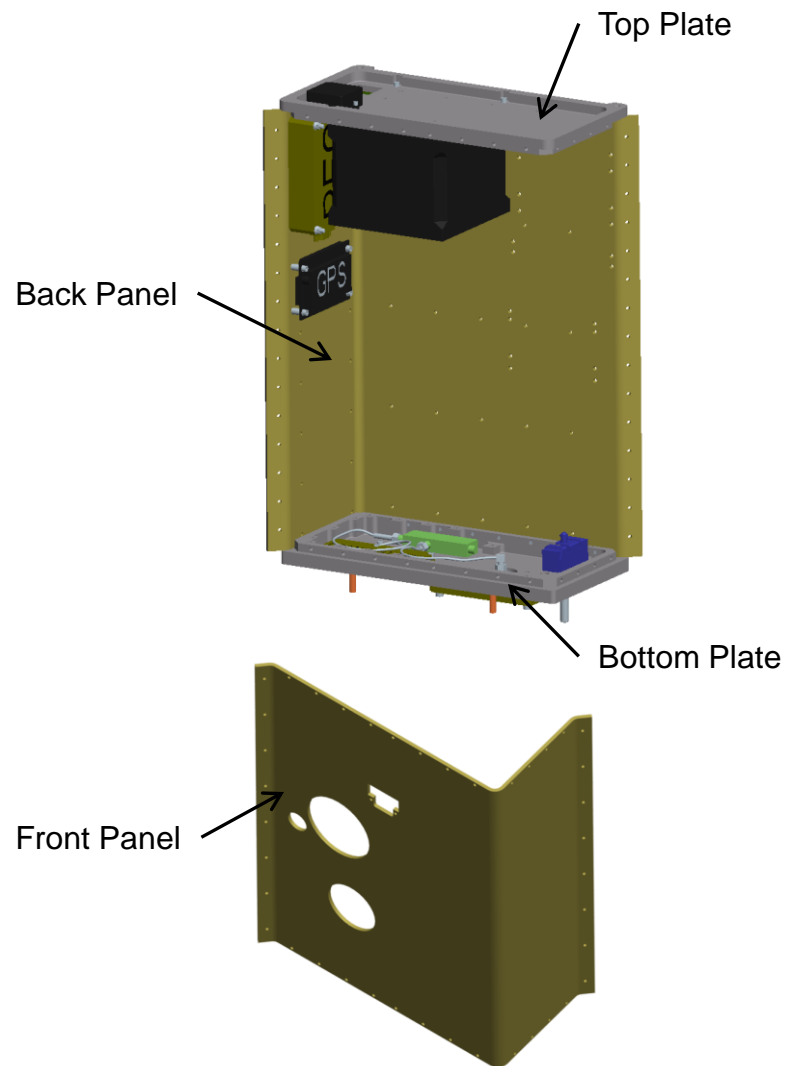
- 469.9 in³ (7,700 cm³)

Mass Allocation:

- 26.4 lbs (12 kg)

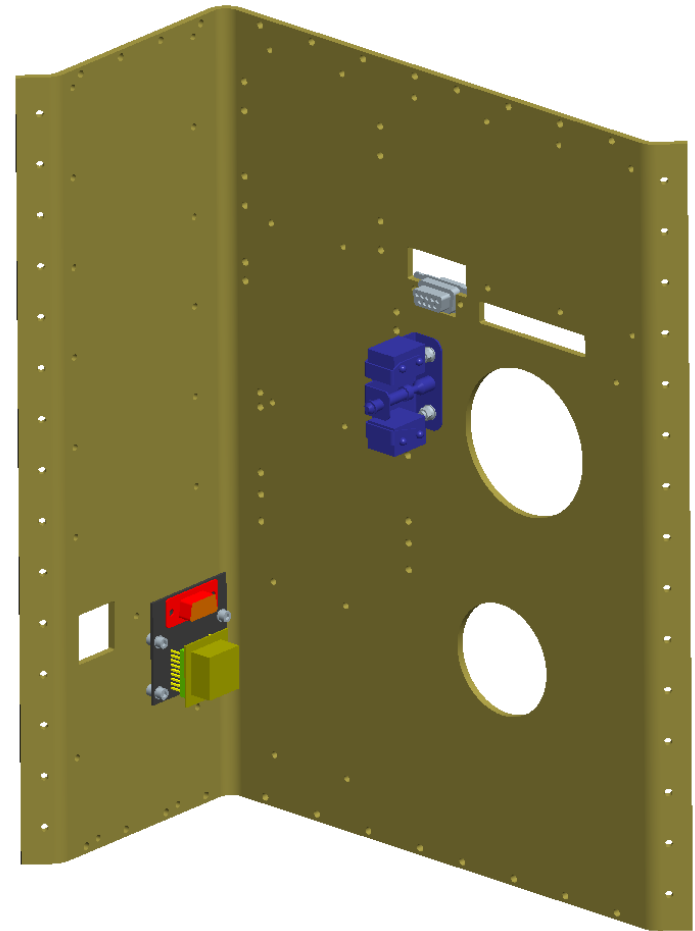


- **Four piece primary structure**
 - Reduced from 7 pieces in Phase 1
- Customizable mounting on panels for mission to mission flexibility
 - Maintained from Phase 1
- Panels acting as structure allow for internal volume to be maximized
 - Significant improvement over Phase 1 frame design
- Distributed loading
 - Improvement over Phase 1 point loading
- Two guide rails in opposite corners allow for the potential of wrap around solar panels and increase external packaging volume
 - Reduced keep out zones from Phase 1
- Two panels allow for a “flat sat” integration of internal components



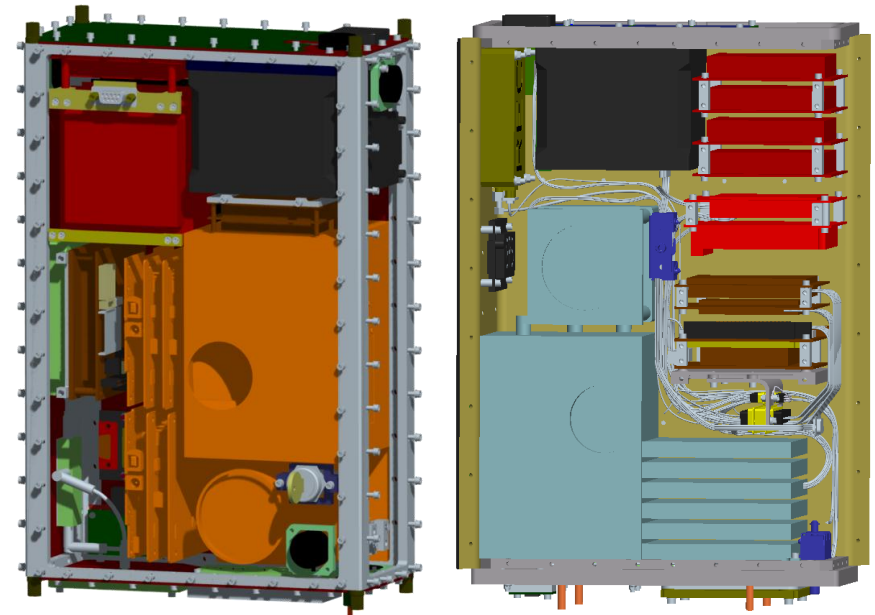
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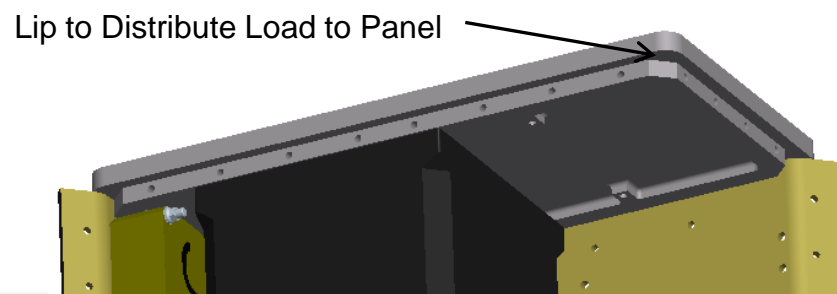
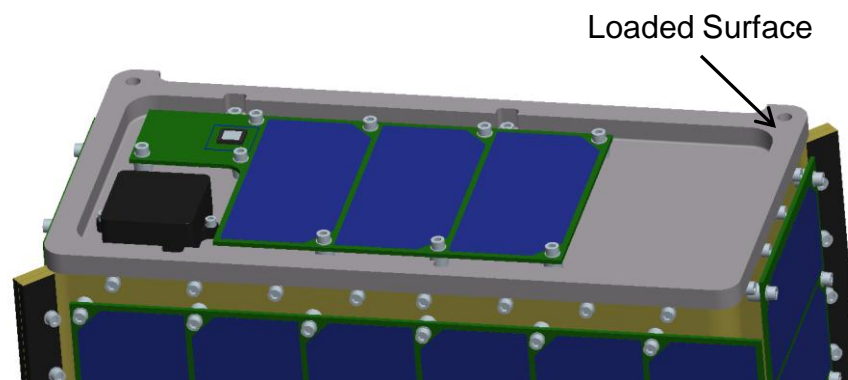
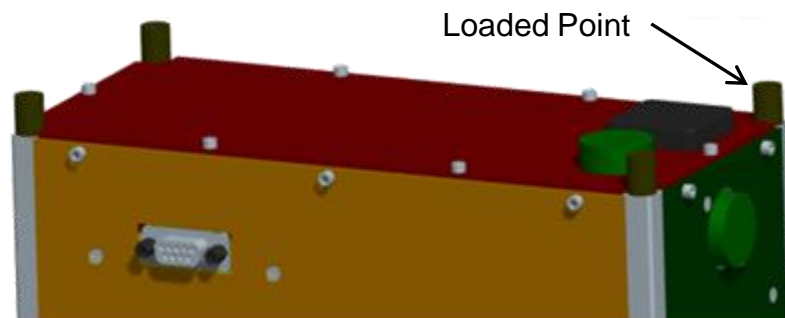
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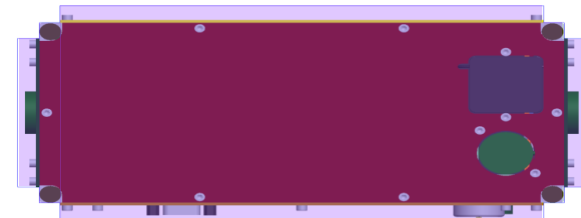
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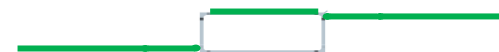


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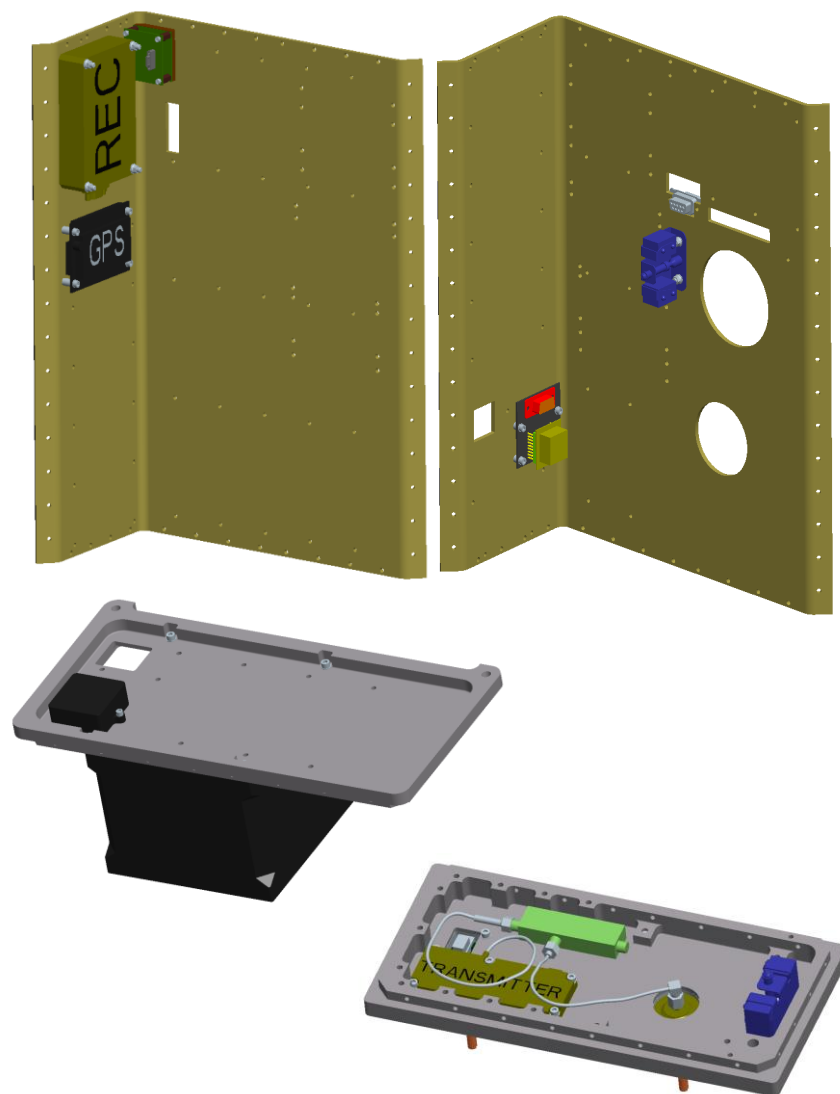
Stowed



Deployed

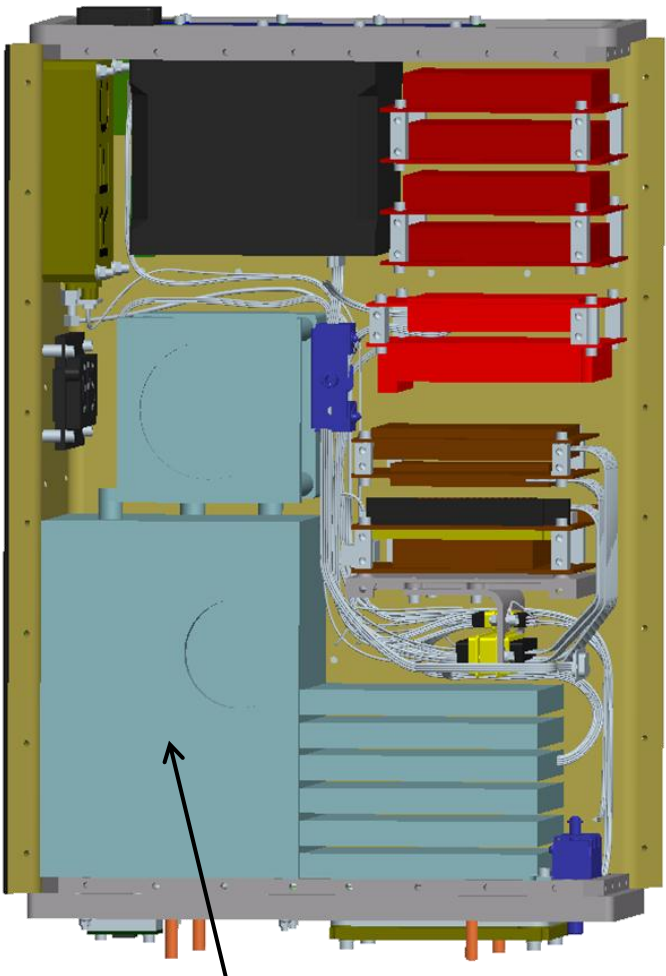
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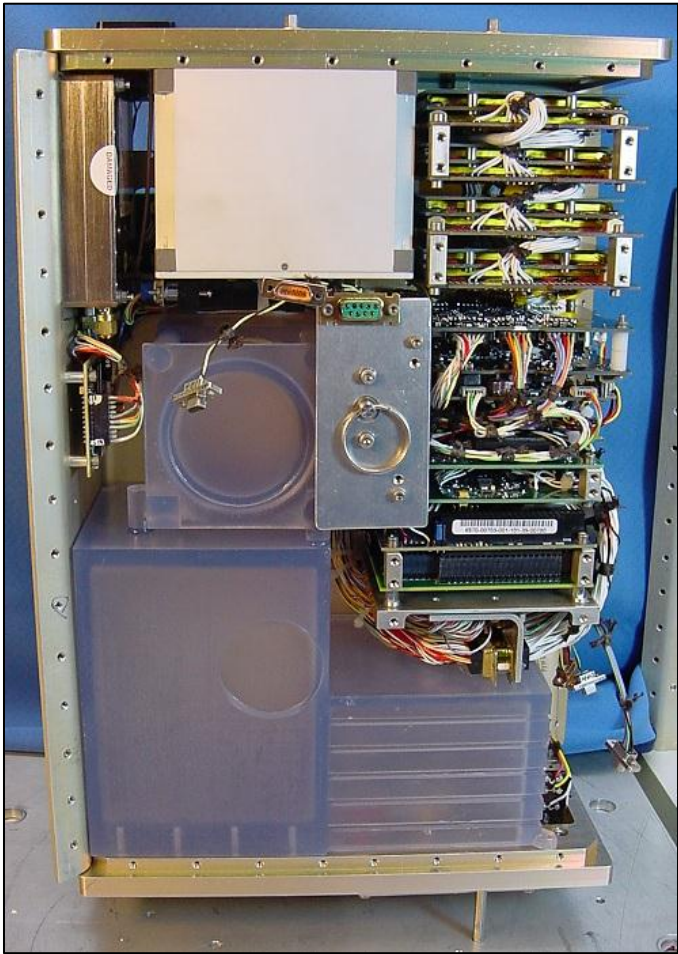
Phase 2: Satellite Packaging Example (CloudSat)

SSAT CAD



Instrument (about 3U or ½ the internal volume)

SSAT Demo Unit



Phase 2: Deployer

External Dimensions:

- 18.92 x 15.88 x 6.50 in (48.06 x 40.33 x 16.51 cm)

Internal Allocation:

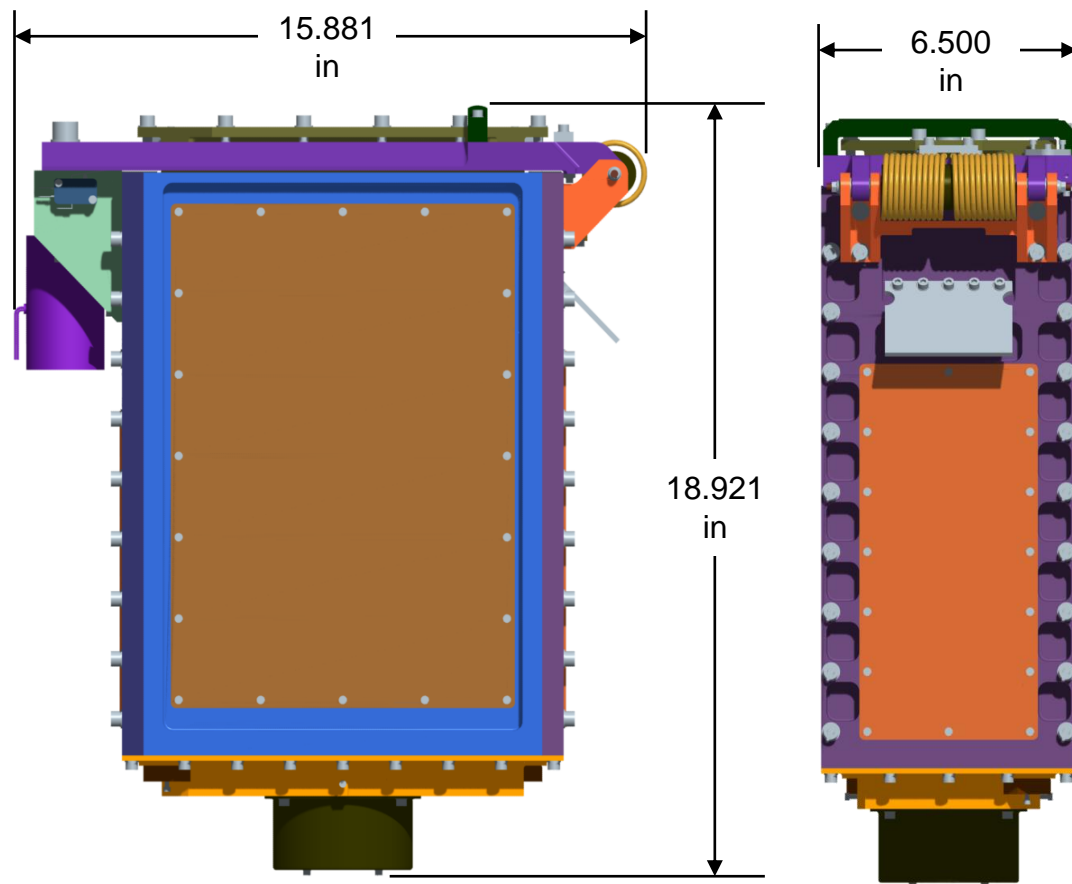
- 14.20 x 9.00 x 4.00 in (36.07 x 22.86 x 10.16 cm)
- 0.375 in (0.95 cm) allowed for protrusions

Mass Allocation:

- 26.4 lbs (12 kg)

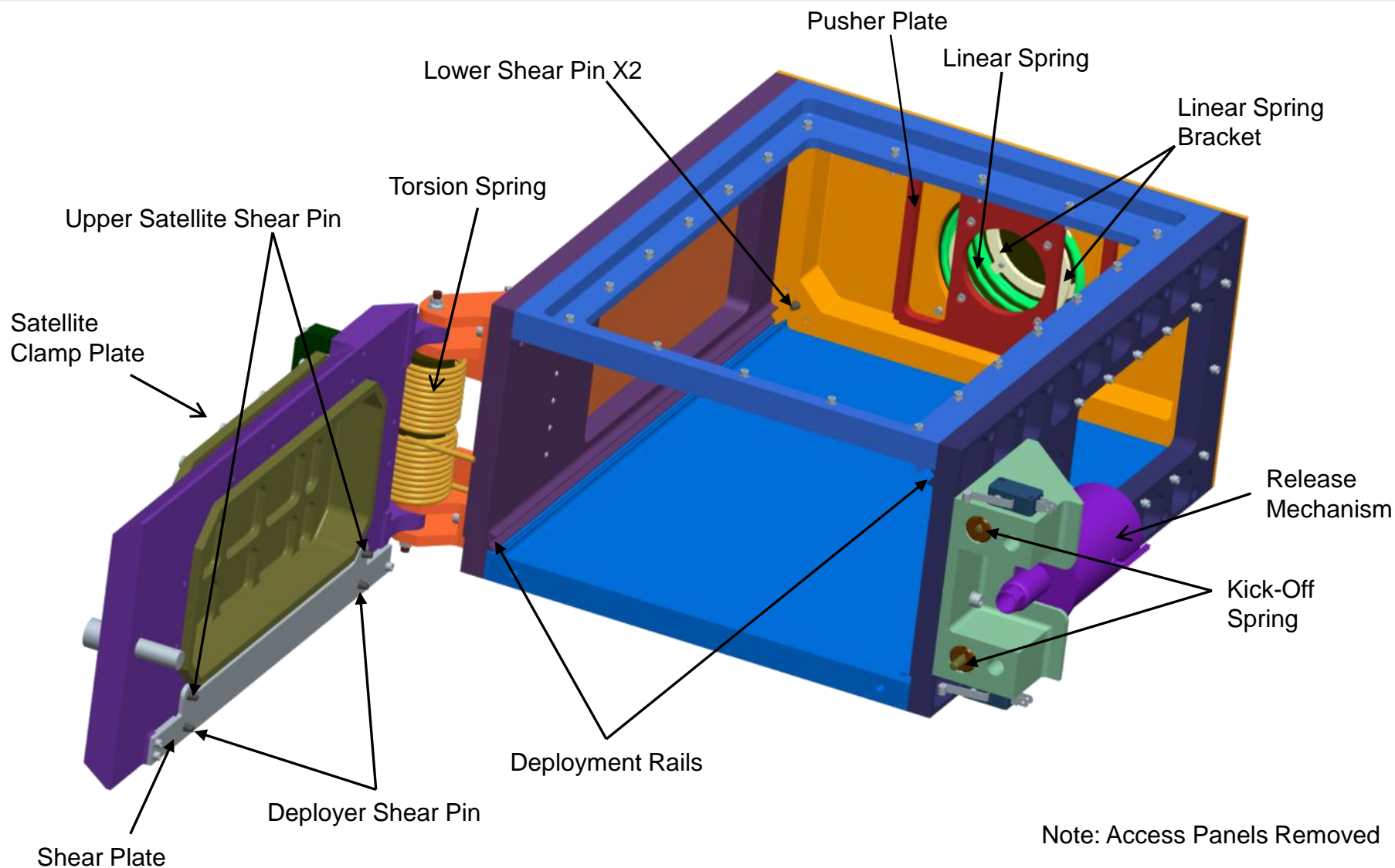
Satellite Exit Velocity:

- 1.26 m/s @ 12 kg



0.375 inch allocation for satellite protrusions (green)

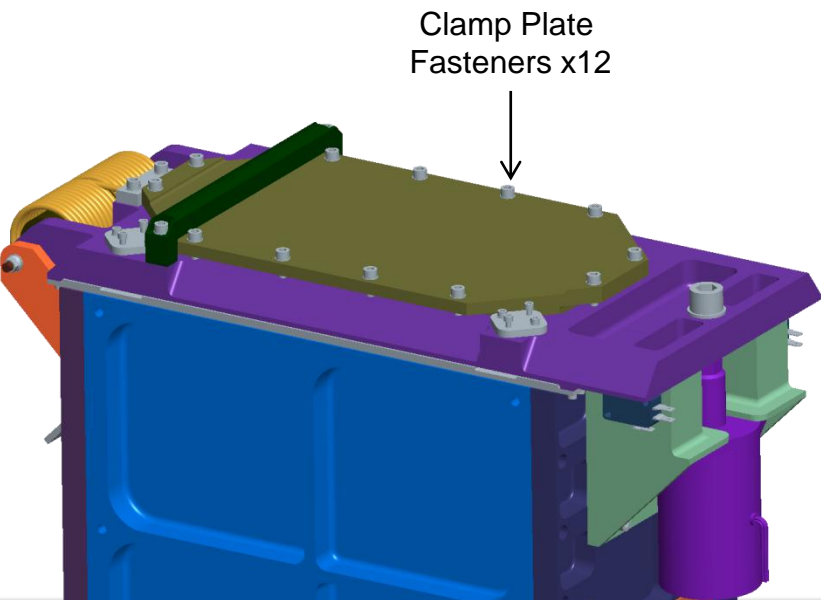
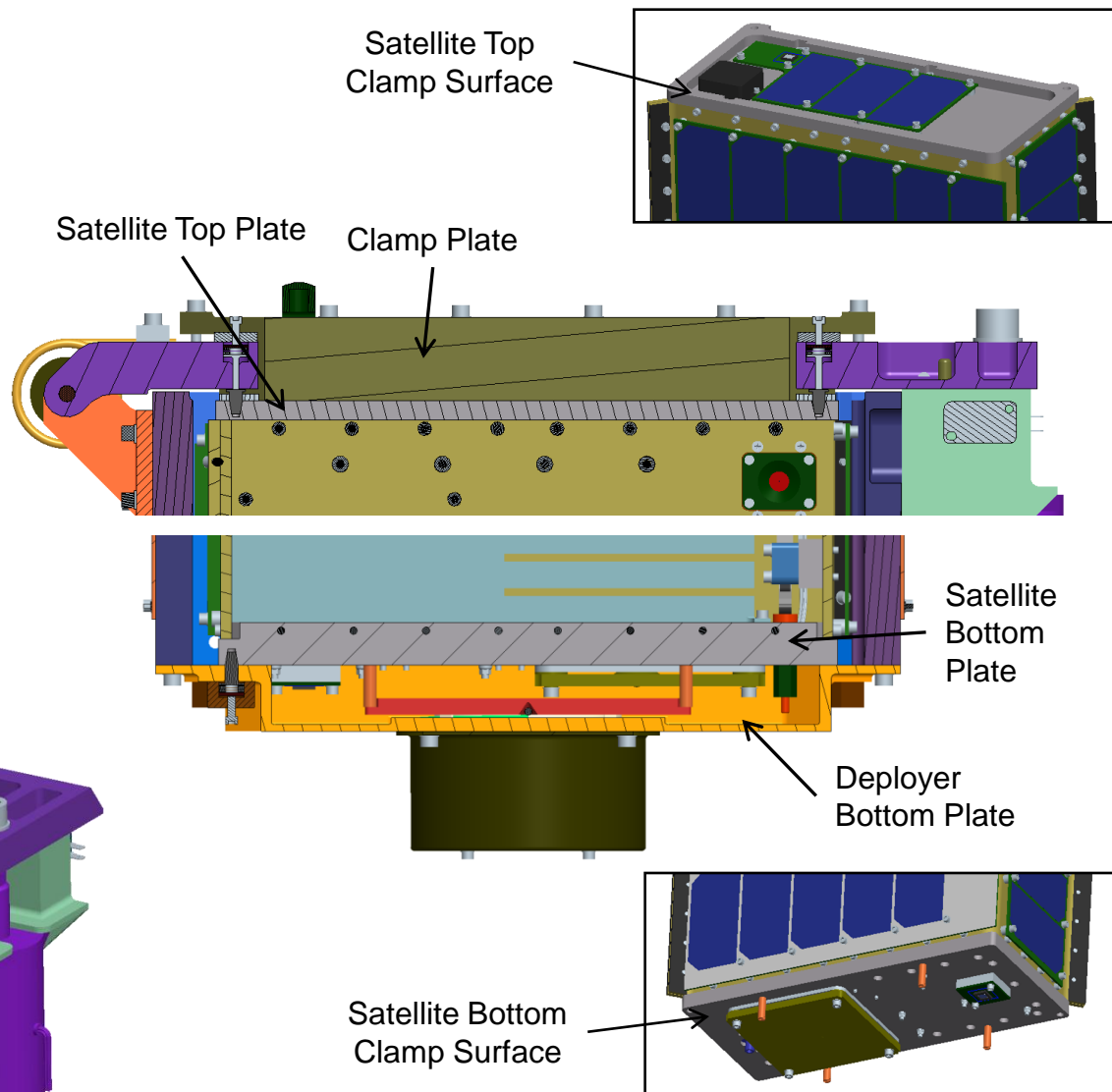
Phase 2: Deployer Overview



Phase 2: Deployer Axial Constraint

Axial Satellite Constraint

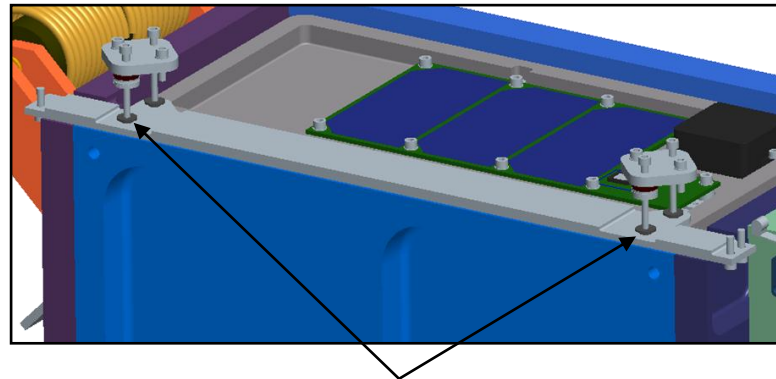
- Clamp plate at the door compresses satellite against the bottom plate of the deployer
- Controlled fastener torques used to create ≈ 630 lbf of preload



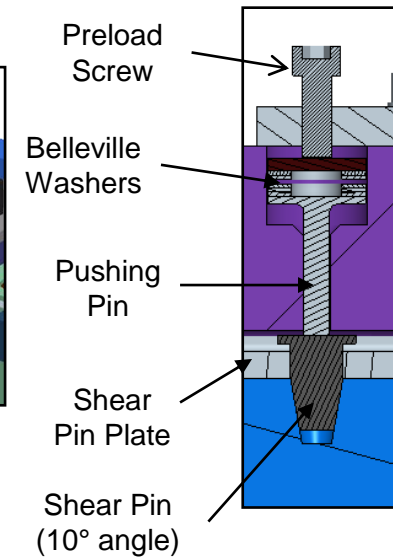
Phase 2: Deployer Lateral Constraint

Lateral Satellite Constraint

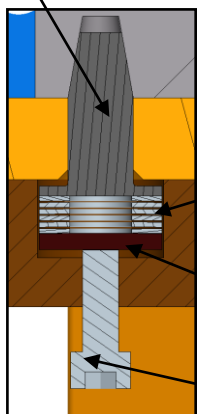
- Pins located at the top and bottom of the satellite
- Angled 10° for ease of extraction
- Preloaded to 50 lbf to ensure constant contact



(4) Top Shear Pins: (2) Satellite & (2) Deployer



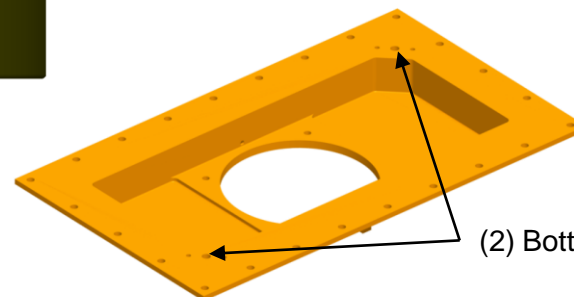
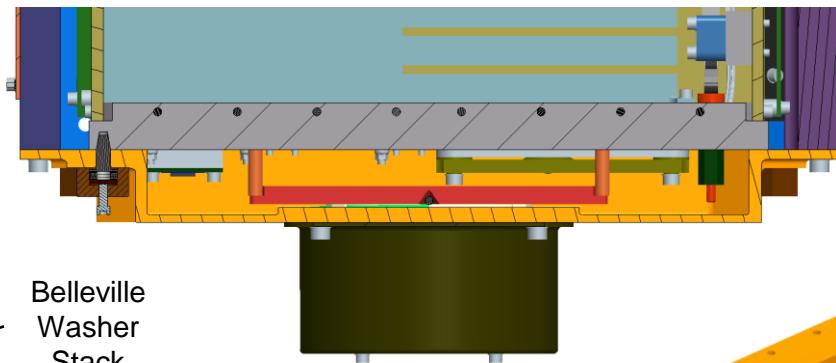
Shear Pin
(10° angle)



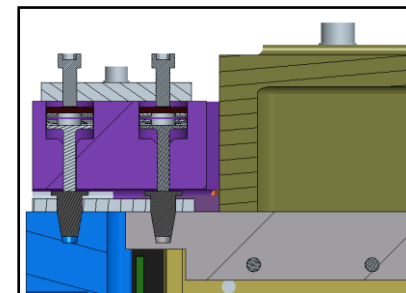
Belleville
Washer
Stack

Pushing
Plate

Preload Screw



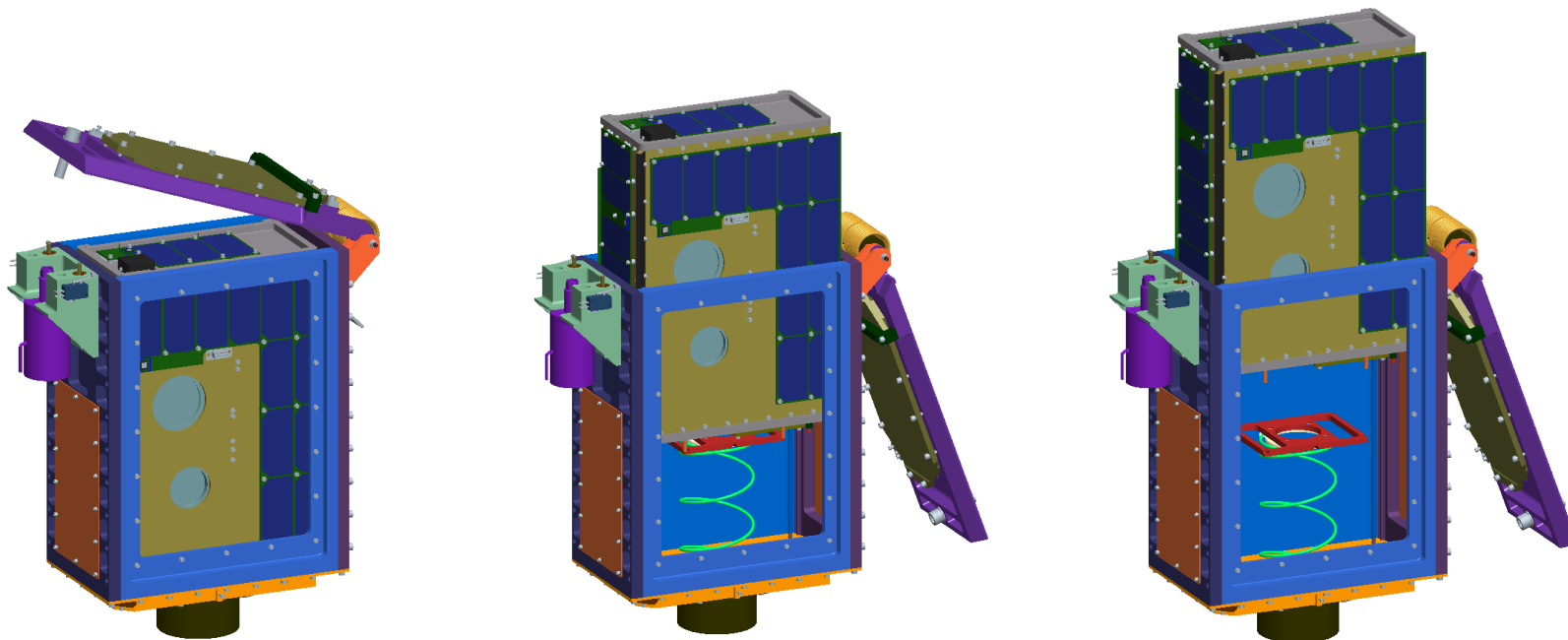
(2) Bottom Shear Pins



Phase 2: Deployment

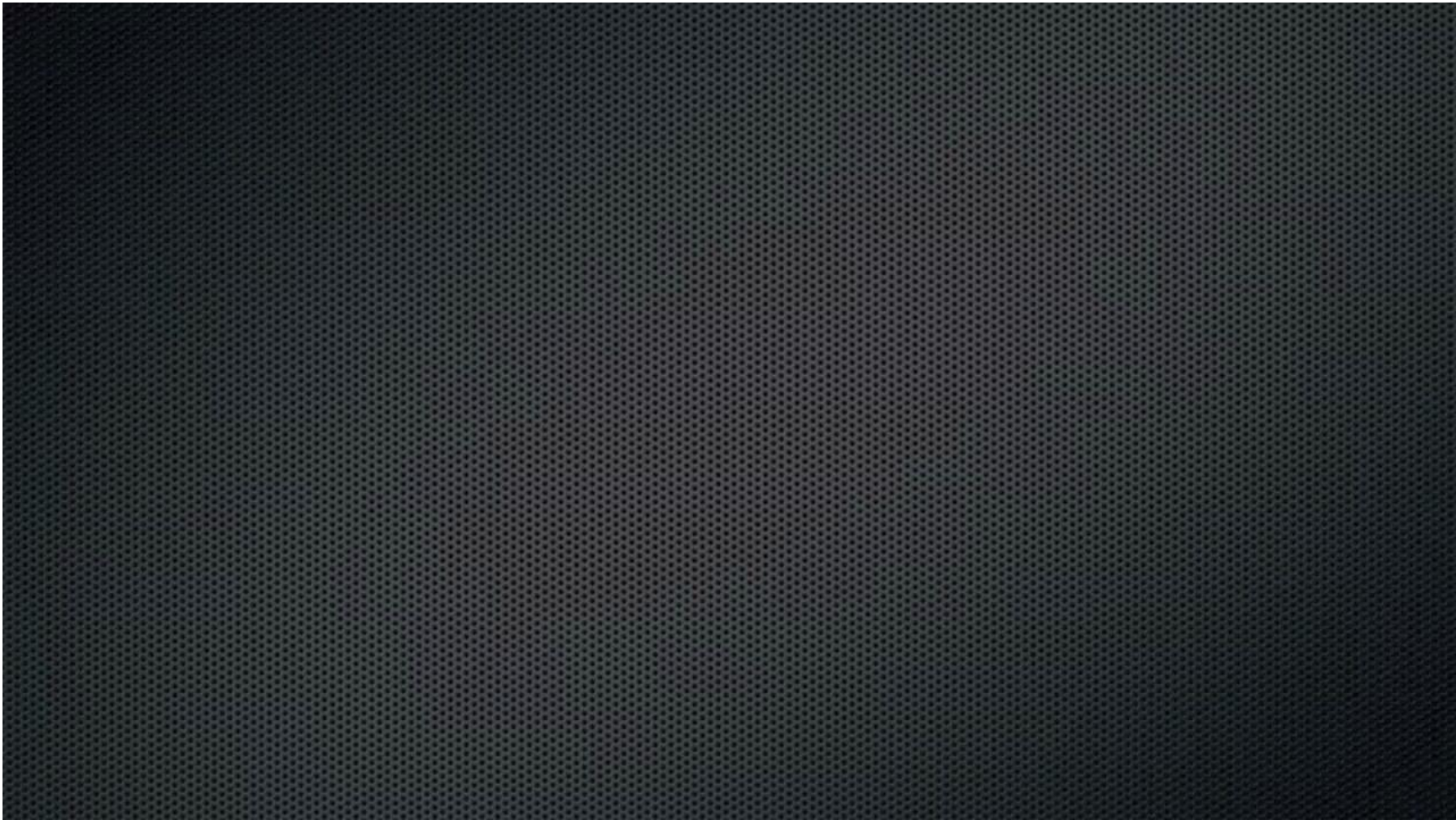
Deployment sequence:

1. Deployment is initiated by the non-explosive actuator releasing the door bolt
2. Kick-off and torsion springs open deployment door ahead of satellite
3. Shear plate and upper pins are retracted by the door
4. Linear spring pushes the satellite midway, allowing the rails to guide the satellite out
5. Energy absorbing plate reduces door impact and bounce back
6. Satellite leaves the deployer at 1.26 m/s, never touching the door



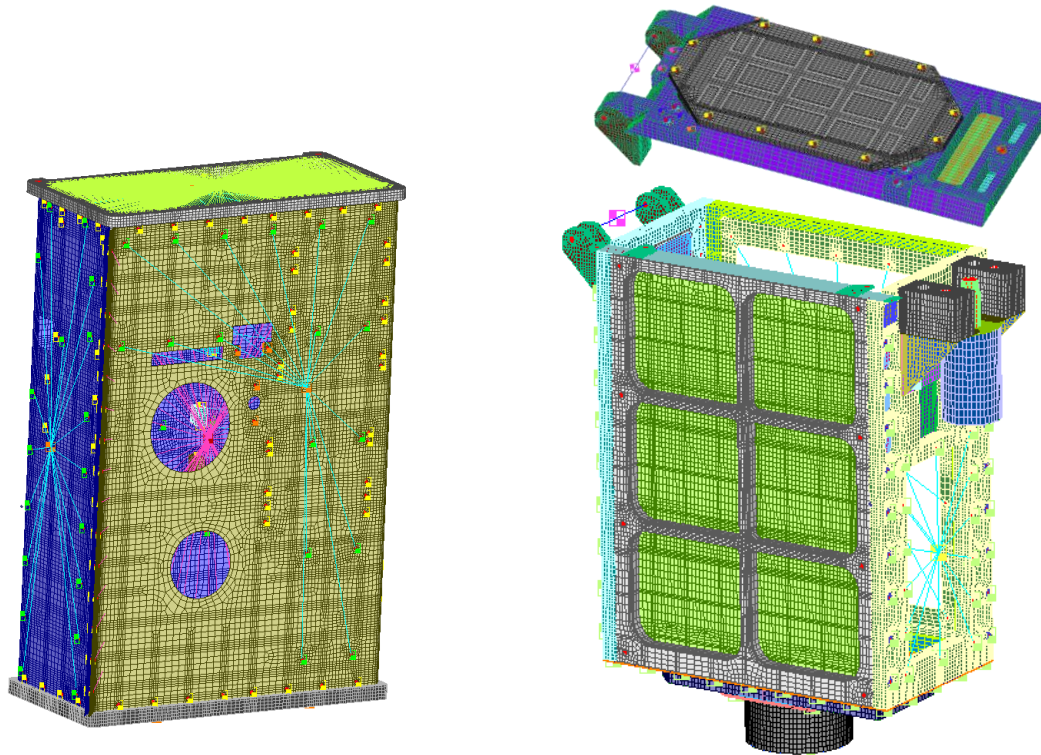


Phase 2: Deployment Video

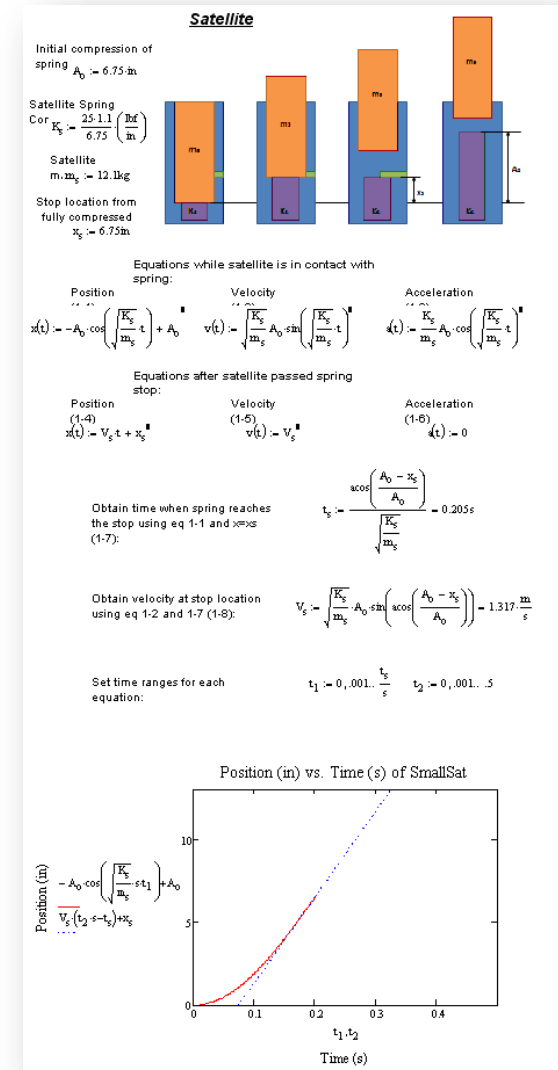


Phase 2: Analysis

- Sized satellite & deployer structures to survive 19 g per axis with no-test safety factors (2.0 & 2.6)
 - Did not have actual loading environments
- Dynamics calculations were used to size springs and predict satellite behavior

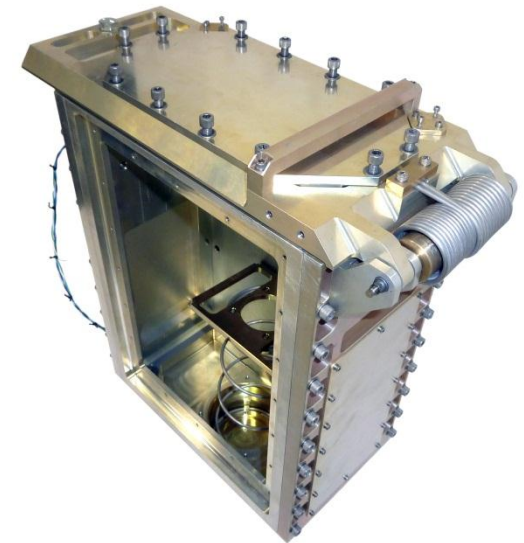


Satellite & Deployer FEMs



Phase 2: Manufacturing & Assembly

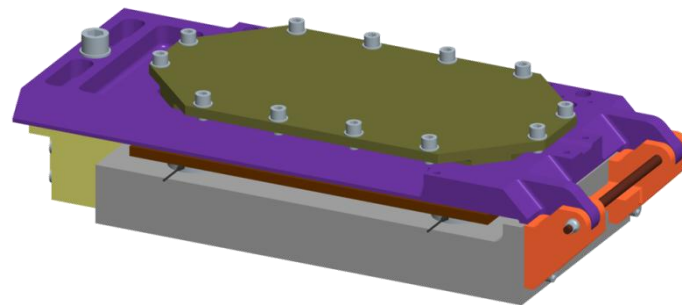
- Flight hardware was manufactured through the NASA GSFC Code 547 Advanced Manufacturing Branch
- Followed written assembly procedures
- Assembled deployer in a Code 548 lab class 10,000 clean bench
- Most difficult part of assembly is having to match drill the pin plate



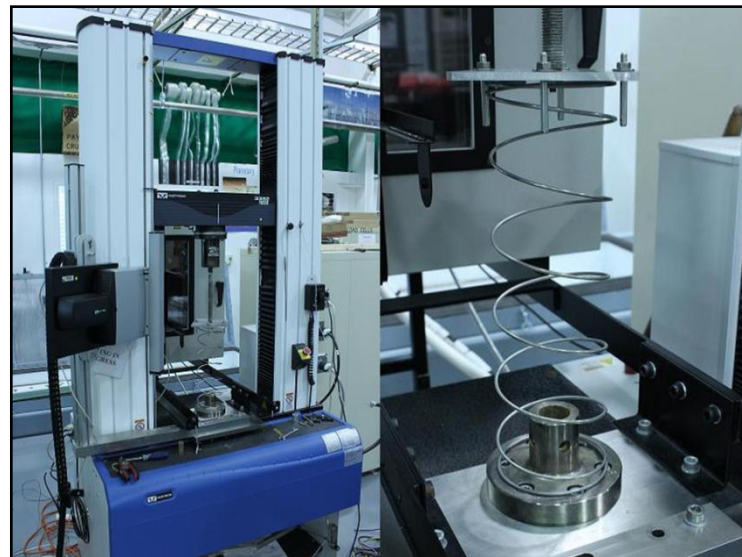
| Deployer Manufacturing Cost | |
|-----------------------------|---------------|
| Item | Cost/unit, \$ |
| Piece Parts | 27,670 |
| Release Mechanism | 9,800 |
| Springs | 1,490 |
| Fasteners | 2,297 |
| Shop Planning Support | 2,845 |
| Total | 44,102 |
| Total +25% Variance | 55,128 |

- Preload Test
- Linear and torsion spring tests
- G-negated deployment test
- Qualification vibration testing

All tests were accompanied by written procedures

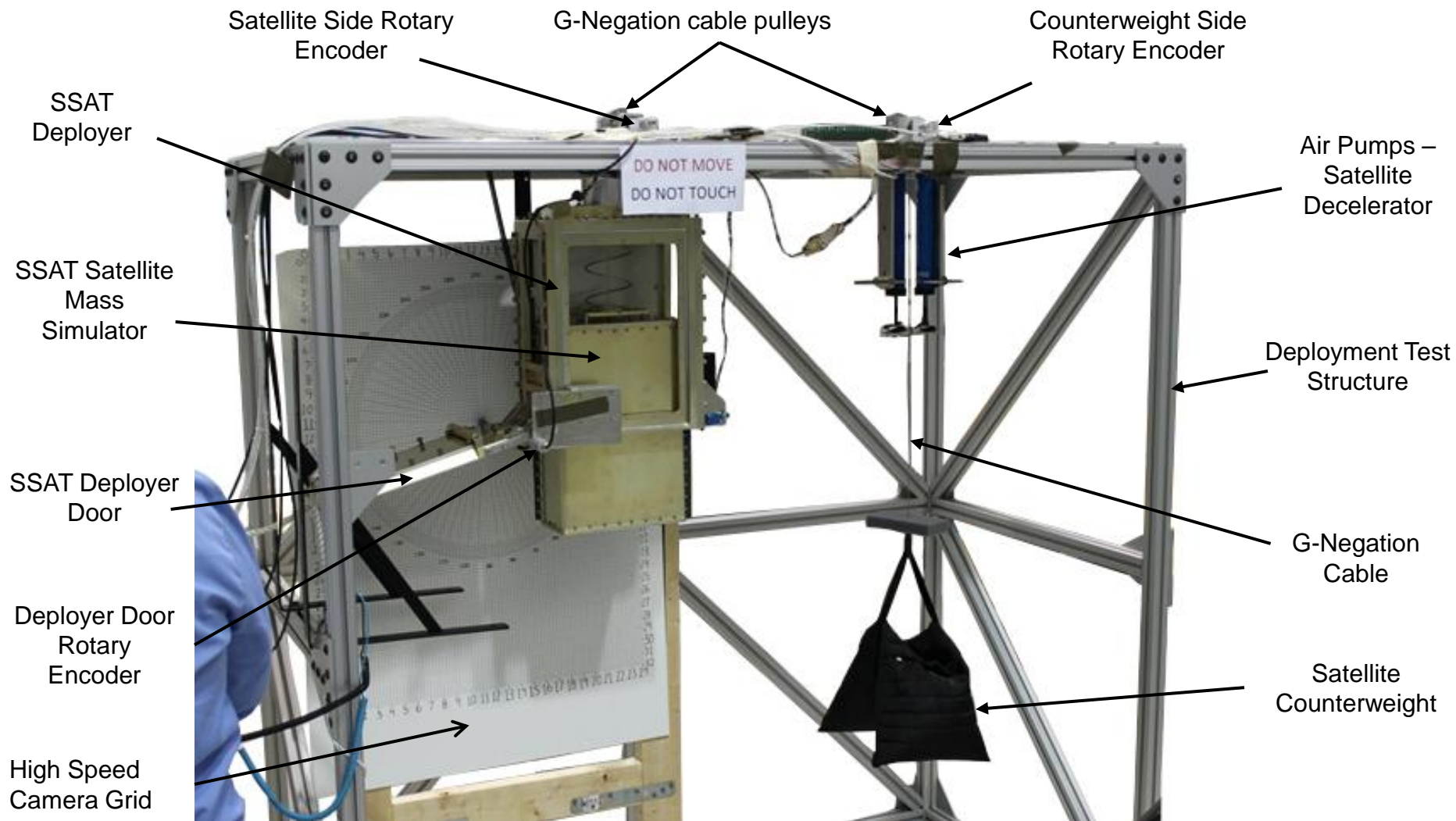


Preload Test 1 Configuration



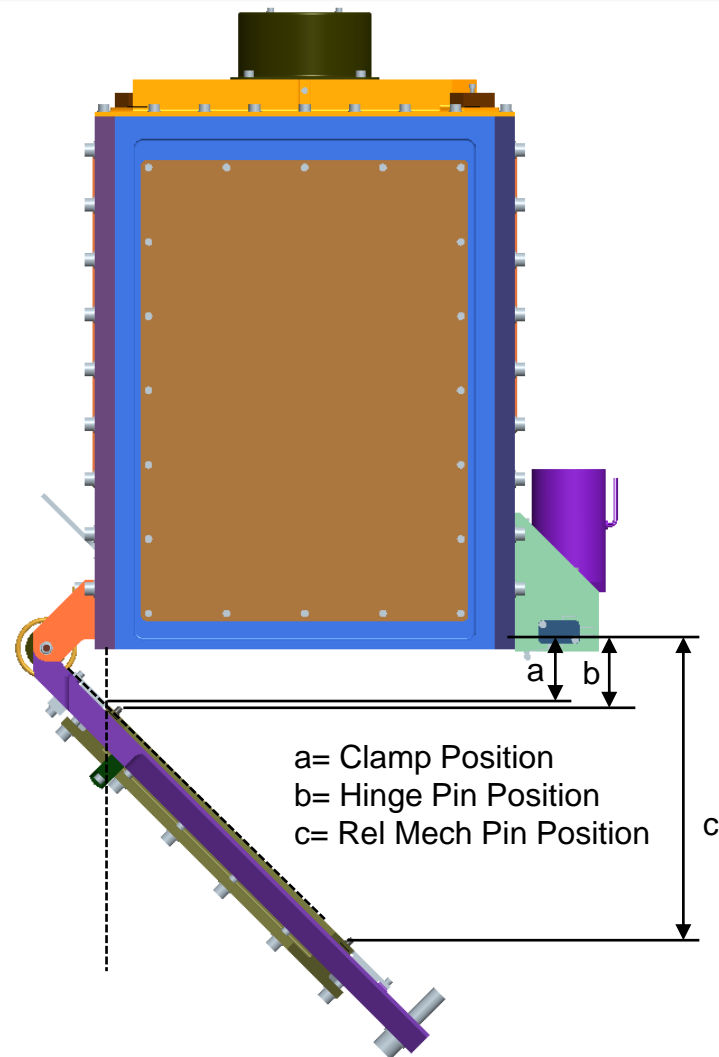
Linear Spring Test

Deployment Test: Overview



(17) deployments were conducted:

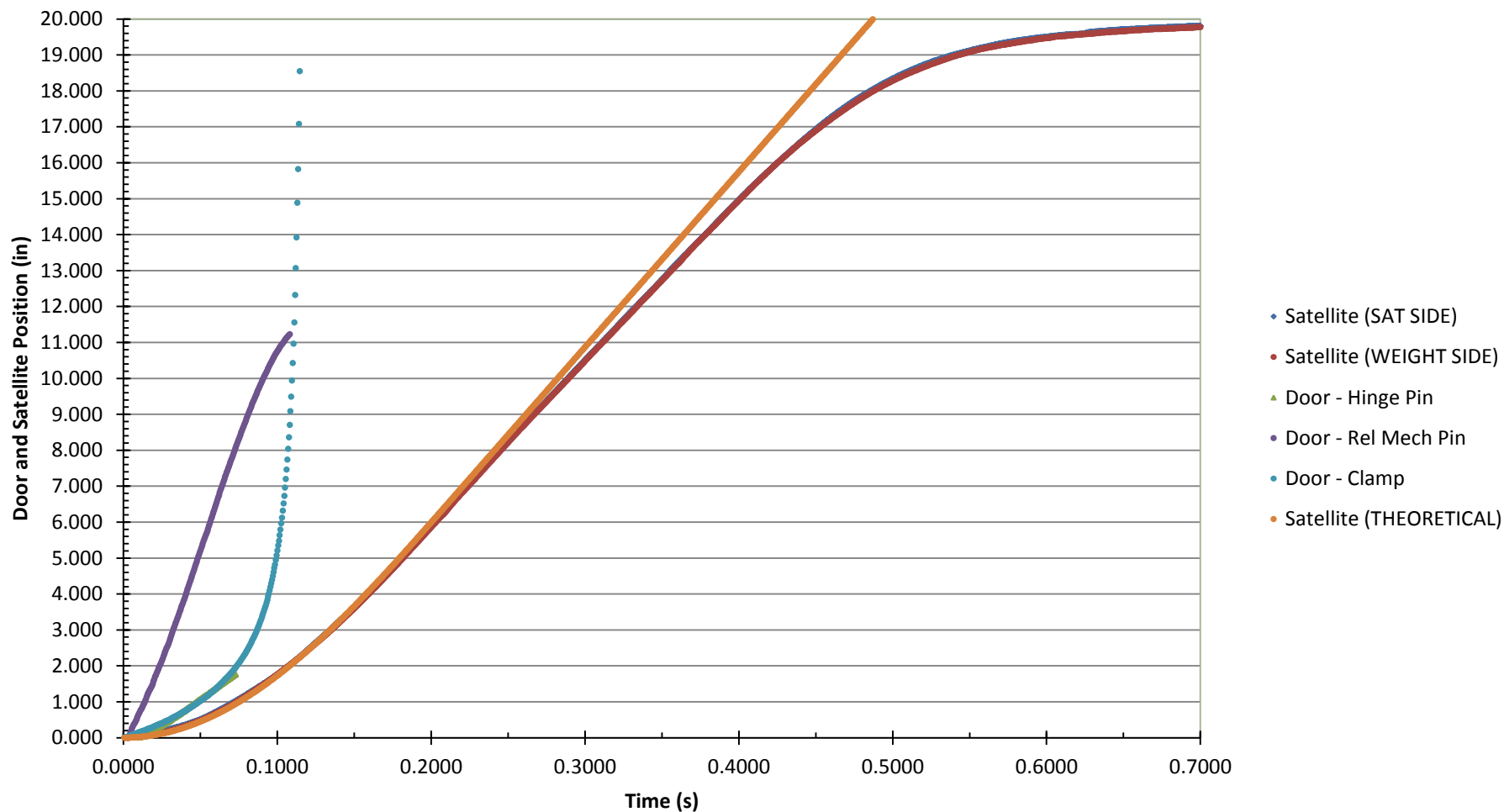
- Space-like deployment: 3
 - Pre vibration test
 - Satellite mass of 6 kg
 - Full preload: satellite and release mechanism
 - 3 Runs completed
- Full Satellite mass deployment: 9
 - 8 Pre-vibration test runs
 - 1 Post-vibration test run
 - Satellite mass of 12 kg
 - Full preload: satellite and release mechanism
- No satellite spring deployments: 5
 - Used to characterize door performance
 - No preload: 3
 - Release mechanism preload only: 1
 - Full preload: Release mechanism and satellite (no pins) 1



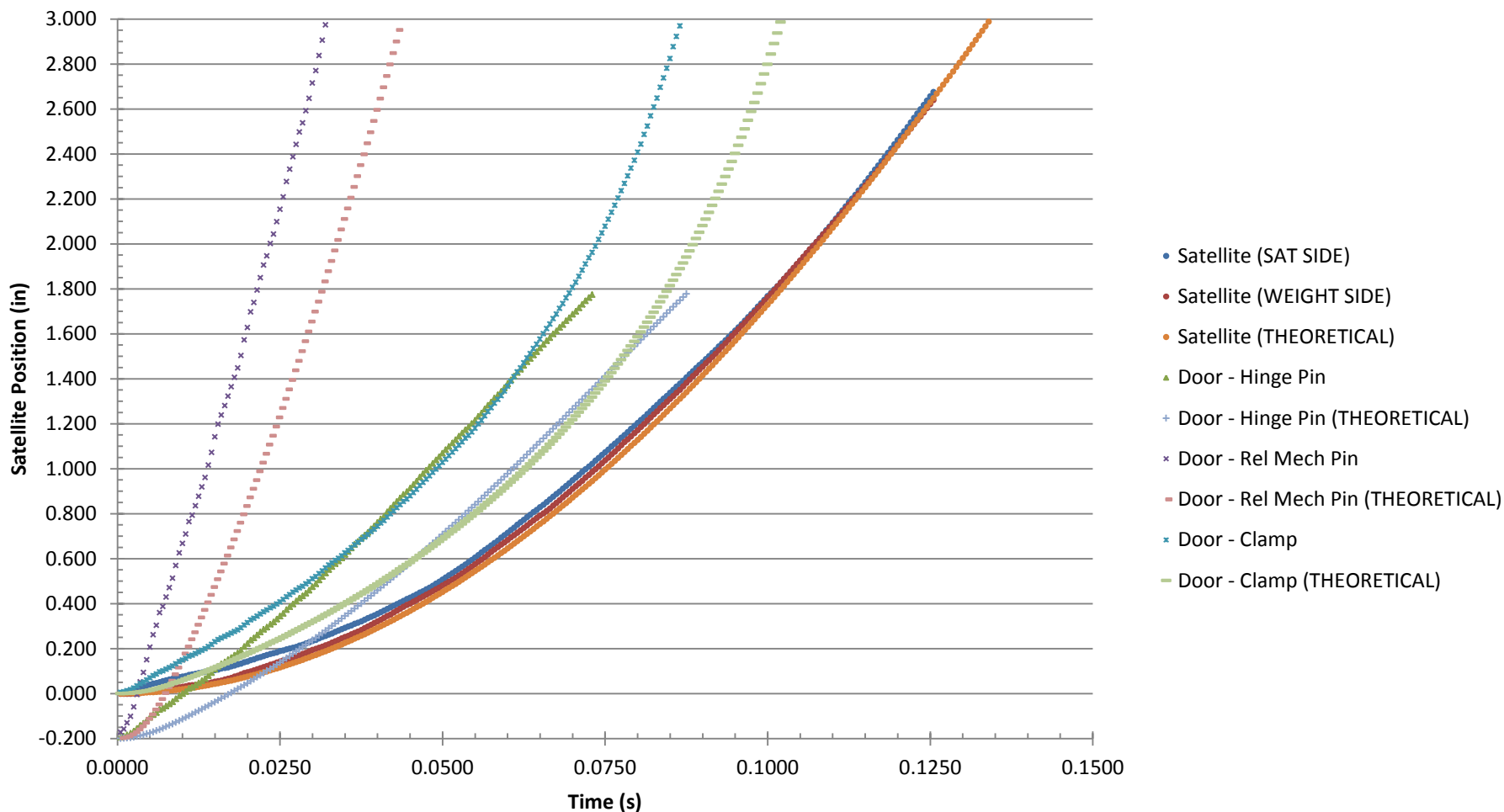
Distances a, b and c are used to compare with satellite position for re-contact analysis



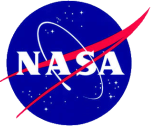
Results: Space-like Deployment Run 1



- The satellite does not re-contact the door on Hinge Side Pin, Release Mechanism Pin nor Door clamp
- Satellite performance is almost identical to predicted data



- Pins initial position is -.200 because they are embedded into the satellite and deployer
- The satellite preload is causing an initial kick on the door, making the pins and clamp move faster than expected



Deployment Test: Summary



Deployment test results showed:

- Successful separation of release mechanism
- Successful separation of door from satellite/deployer
- Successful separation of satellite from deployer
- No re-contact of satellite and door during satellite ejection
- Successful deployment after qualification level vibration tests
- Door performance, satellite performance and satellite exit velocity was not as predicted
 - Door had an initial push from the satellite preload that accelerated it faster than predicted
 - Exit velocity achieved was 85% - 93% of theoretical value

Qualification Vibration Testing

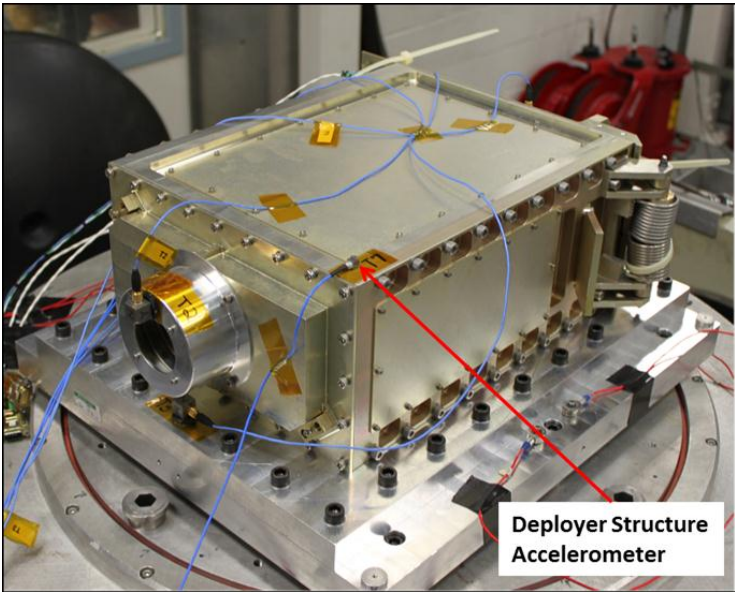
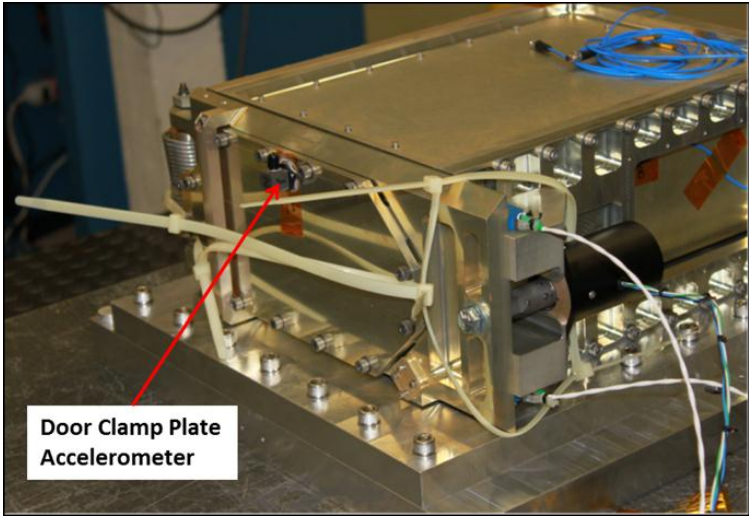
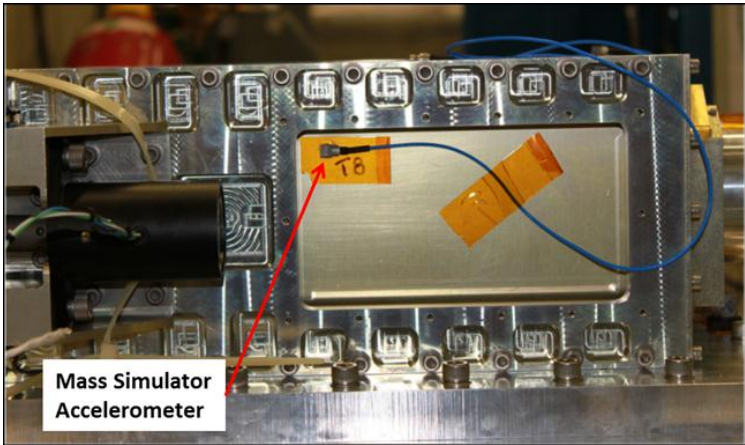
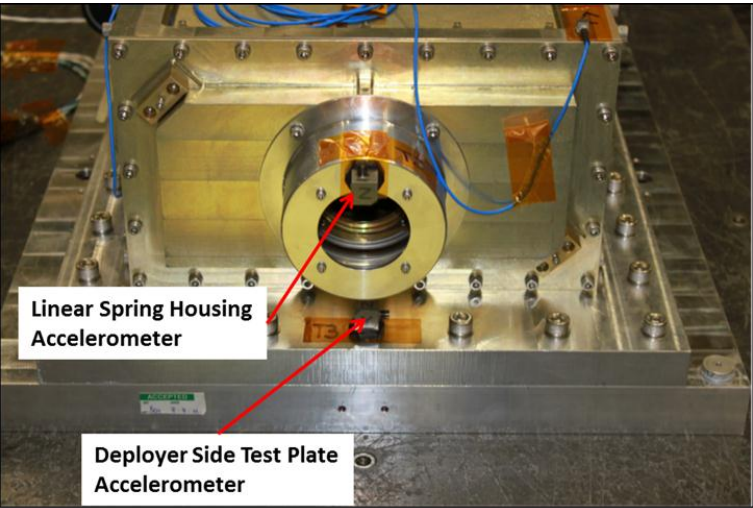
- Sine Burst – 23.75 g
- Sine Sweep – 5-20 Hz @ 0.63 in, 20-100 Hz @ 12.5 g
- Random Vibration – 14.1 grms per GEVS GSFC-STD-7000
- Shock – Per capability of facility shaker table

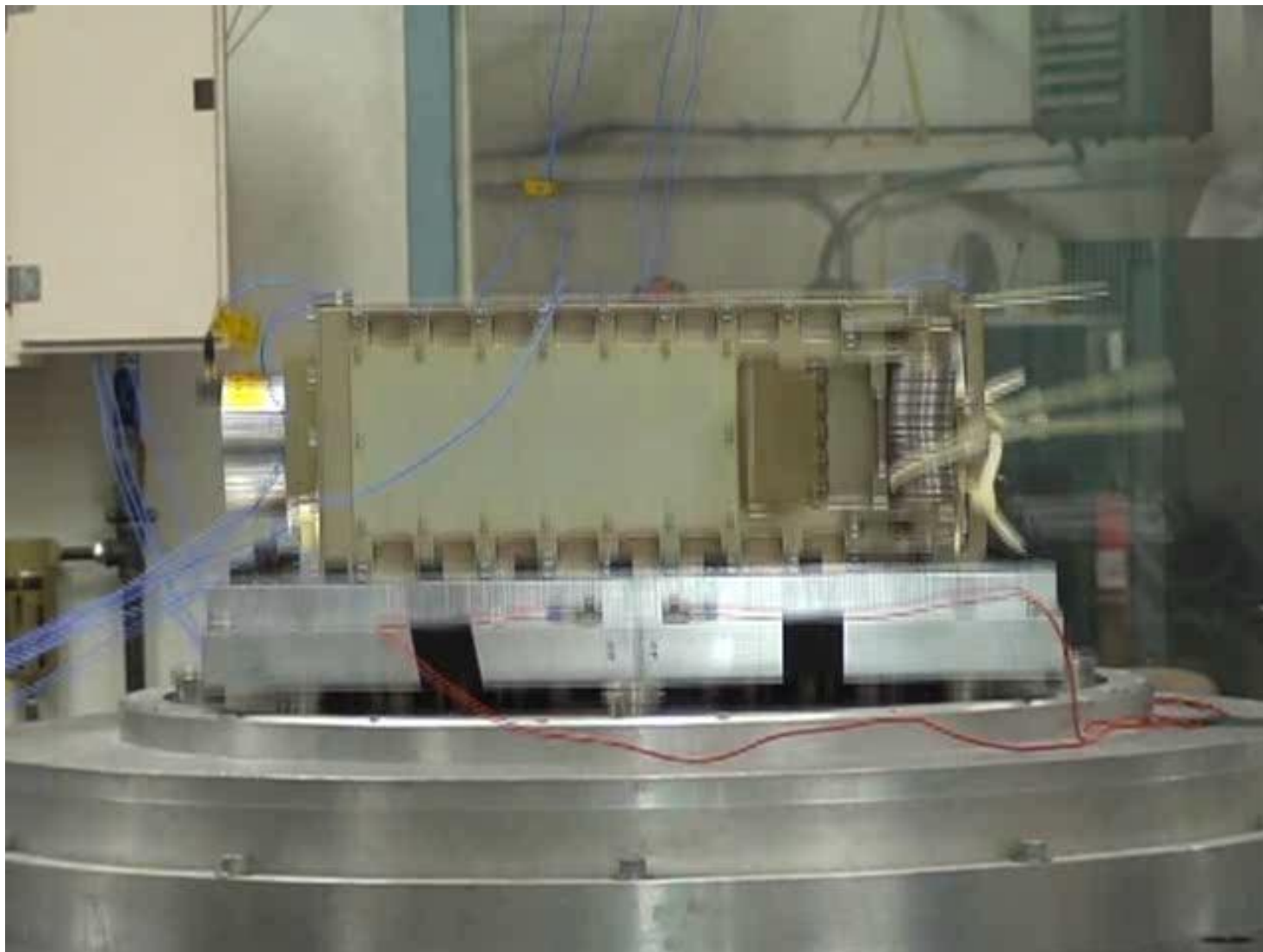


Test Sequence

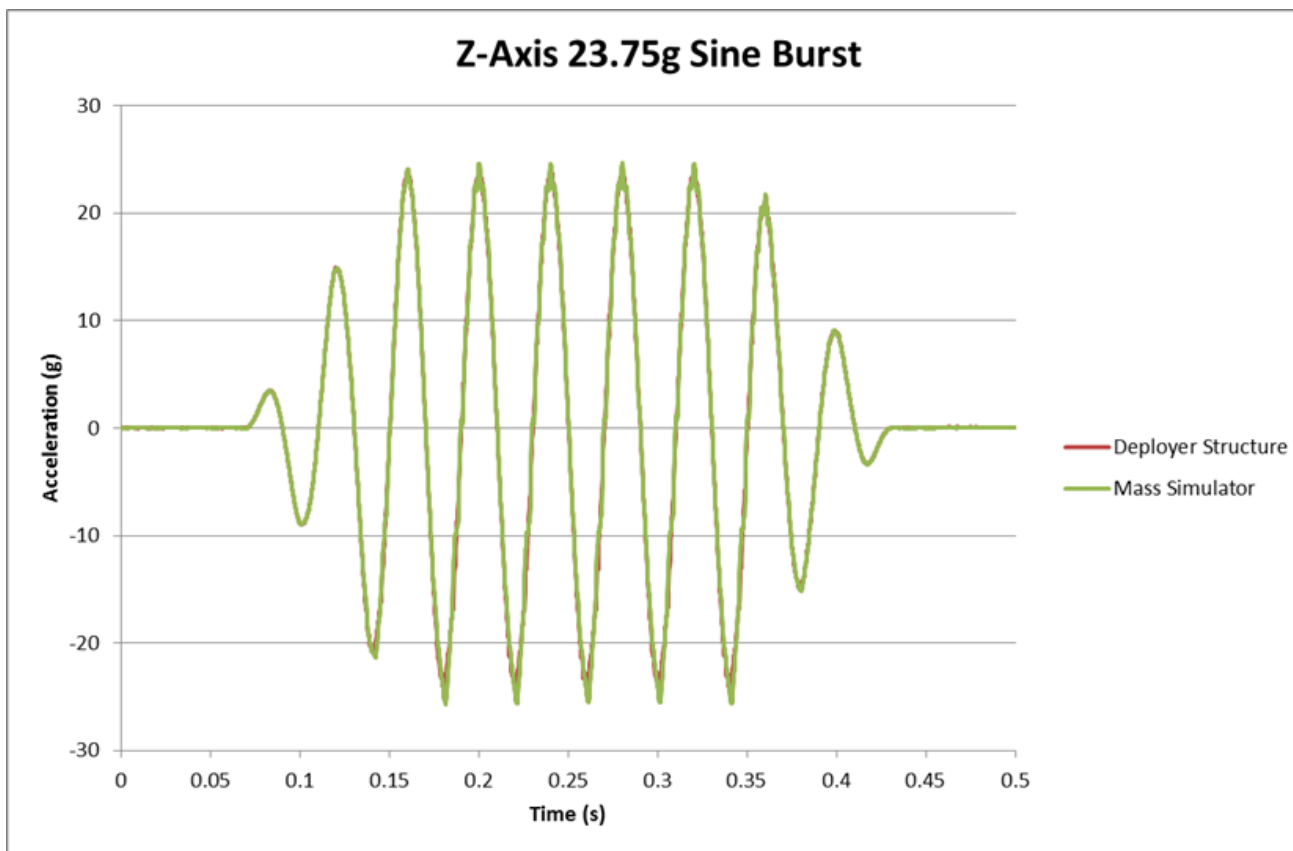
1. Low Level Signature Sweep
2. ½ Full Level Sine Burst (-12dB, -6dB, -3dB, 0dB)
3. Low Level Signature Sweep
4. Full Level Sine Burst (-12dB, -6dB, -3dB, 0dB)
5. Low Level Signature Sweep
6. ½ Full Level Sinusoidal Vibration
7. Low Level Signature Sweep
8. Full Level Sinusoidal Vibration
9. Low Level Signature Sweep
10. Workmanship Level Random Vibration
11. Low Level Signature Sweep
12. Qualification Level Random Vibration
13. Low Level Signature Sweep
14. Shock (-12dB, -6dB, -3dB, 0dB)
15. Low Level Signature Sweep

Vibration Test: Accelerometer Locations



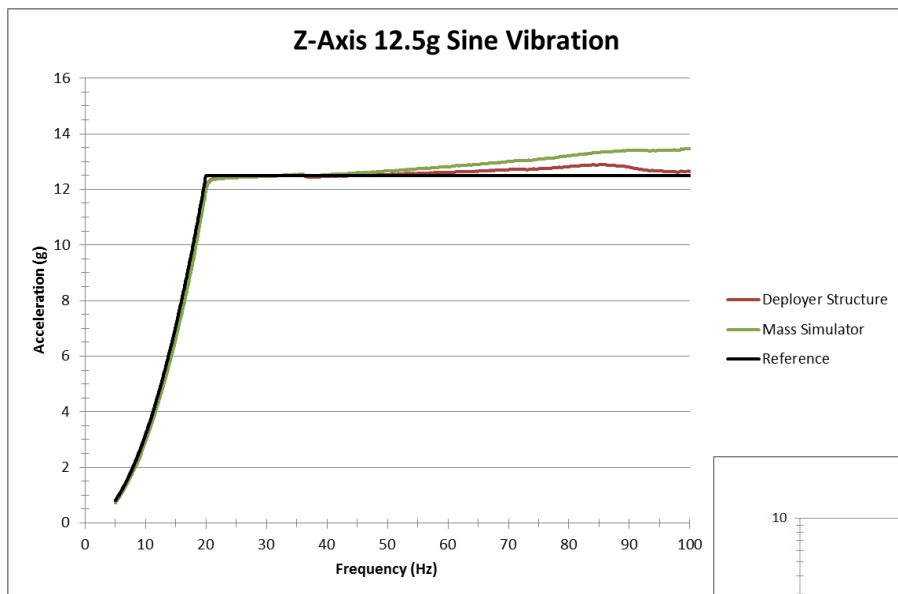


Vibration Test: Results



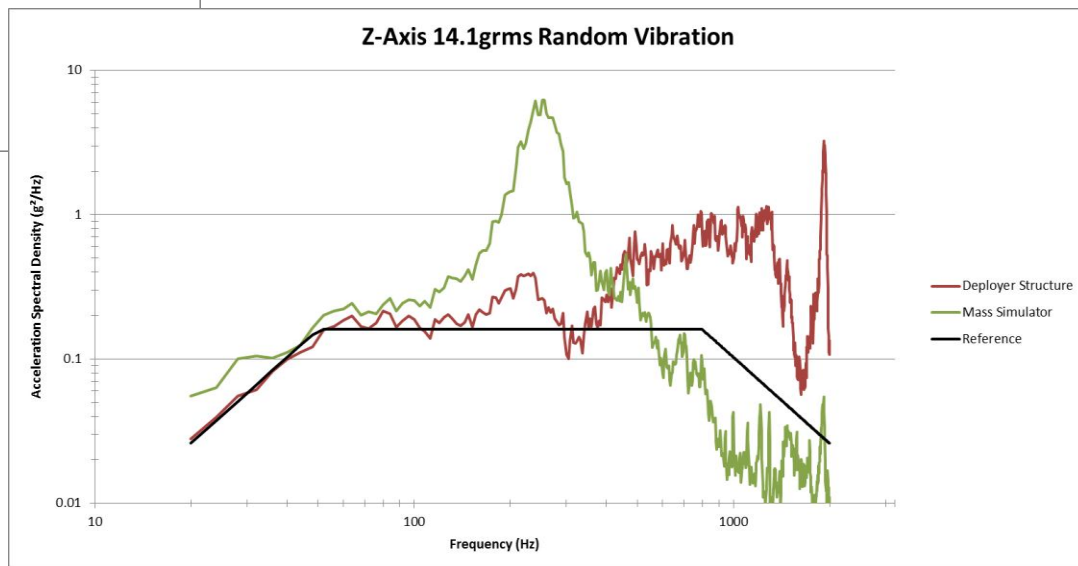
- Deployer structure and mass simulator are moving together under the 23.75 g acceleration load

Vibration Test: Results

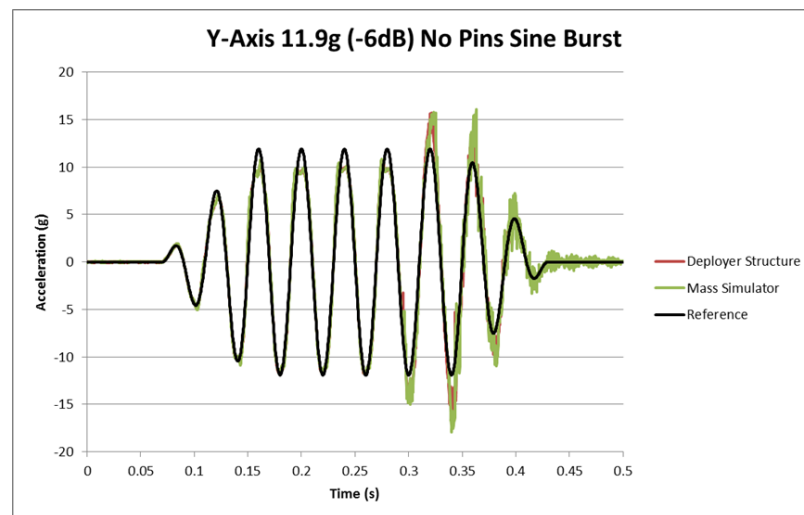
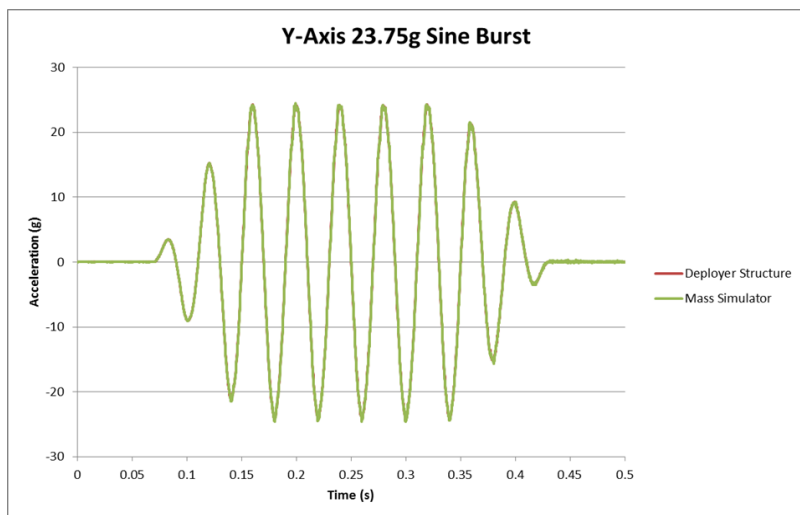


- As expected not much happened in the low frequency range with 1st modes in the 200-300 Hz range

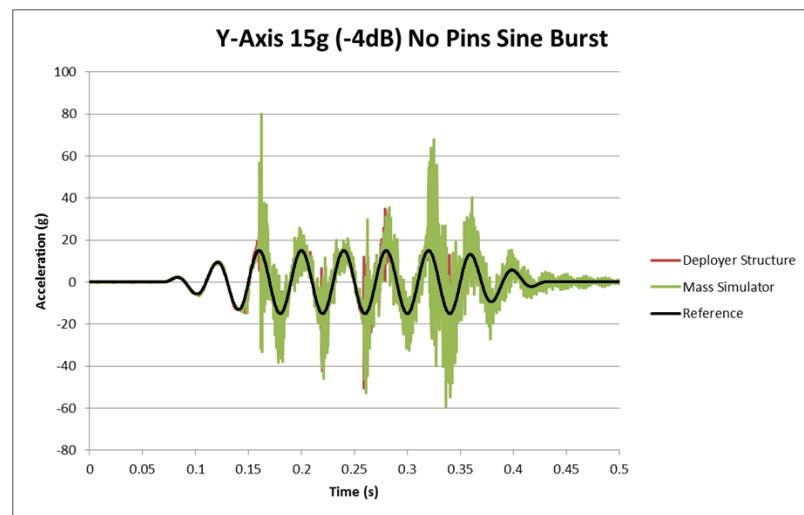
- Vibe plate caused some noise in the high frequency range over 1000 Hz (deployer structure)

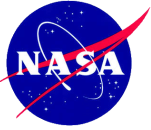


Vibration Test: No Pins Sine Burst Test



- A Y-axis sine burst test was conducted on the deployer structure less the shear pins and linear spring to evaluate the effectiveness of the pins in comparison to the friction generated by the axial preload
- The mass simulator first began to slip at 11.9 g and was definitely moving within in the deployer at 15 g when the test was stopped
- Results demonstrate the need for the pins at the 23.75 g qualification level and serve as an indication for their effectiveness in the constraint system



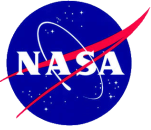


Vibration Test: Summary



The following qualification vibration testing primary objectives were met:

- ✓ There were not any significant structural changes or failures
- ✓ The mass simulator remained fully constrained within the deployer
- ✓ The mass simulator was able to successfully deploy post vibration test



Lessons Learned



- Loads uncertainty has a significant design impact
- Avoid risk and plan to do dynamic analysis even if using MAC curves and assuming system isolation
- Not having well defined ICDs can cause confusion and design delays
- Developing a system without an integrated schedule is a recipe for shifting to the right
- Torquing fasteners can only provide a preload range
- When applying preload less fasteners can be more effective
- Helicoil inserts do not always break properly at the tang and can interfere with fastener torques
- Preloading the structure adds energy to the system and can be significant enough to increase the speed of the deployer door
- It takes time for a vibe facility to tune their equipment to achieve shock levels



Forward Work



- Pursuing continued work through IRADs
 - Using manufacturing techniques such as wire EDM to reduce the number of joints and save mass
 - Deployment system improvements to increase reliability
 - Investigate methods to improve preload repeatability
 - Compatibility kits for standard 6U satellites
 - 6U satellite deployables such as solar arrays, helical antennae, sun shields, etc.
- Potential for a sounding rocket test flight
- System currently being carried in GSFC proposals and a number of scientists have expressed interest in using the platform
- Show design at various forums and conferences
 - Concept presented last year at the Small Satellite Conference at Utah State University and will be displayed this year



Antares launch
coming soon



Stop out for a visit!